

# **Field Investigations of Lactate-Stimulated Bioreduction of Cr(VI)to Cr(III) at Hanford 100H (FY03-04)**

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**DOE Joint Natural and Accelerated Bioremediation (NABIR) Program and EM Office of Science and Technology Supplemental Call**

# Overall Objective

To carry out field investigations to assess the potential for immobilizing and detoxifying chromium-contaminated groundwater using lactate-stimulated bioreduction of Cr(VI) to Cr(III) at the Hanford 100H site

# Hypothesis

- Lactate (HRC) injection into chromium contaminated groundwater through an injection well will cause bioreduction of chromate [Cr(VI)] and precipitation of insoluble species of [Cr(III)] on soil particles, probably catalyzed at oxide surfaces, at the field scale

# **Project Tasks**

## **Year 1 – Evaluating Pre-Test (Background) Conditions, Conducting an Initial Lactate (HRC) Injection Test and Evaluating its Effectiveness**

**Task 1. Test design and field preparation**

**Task 2. Monitoring and analyzing background conditions**

**Task 3. Development of an initial conceptual model of background hydrogeologic and geochemical conditions**

**Task 4. Conducting an initial test of Lactate (HRC) injection into groundwater and monitoring flow and transport processes associated with chromium bioreduction**

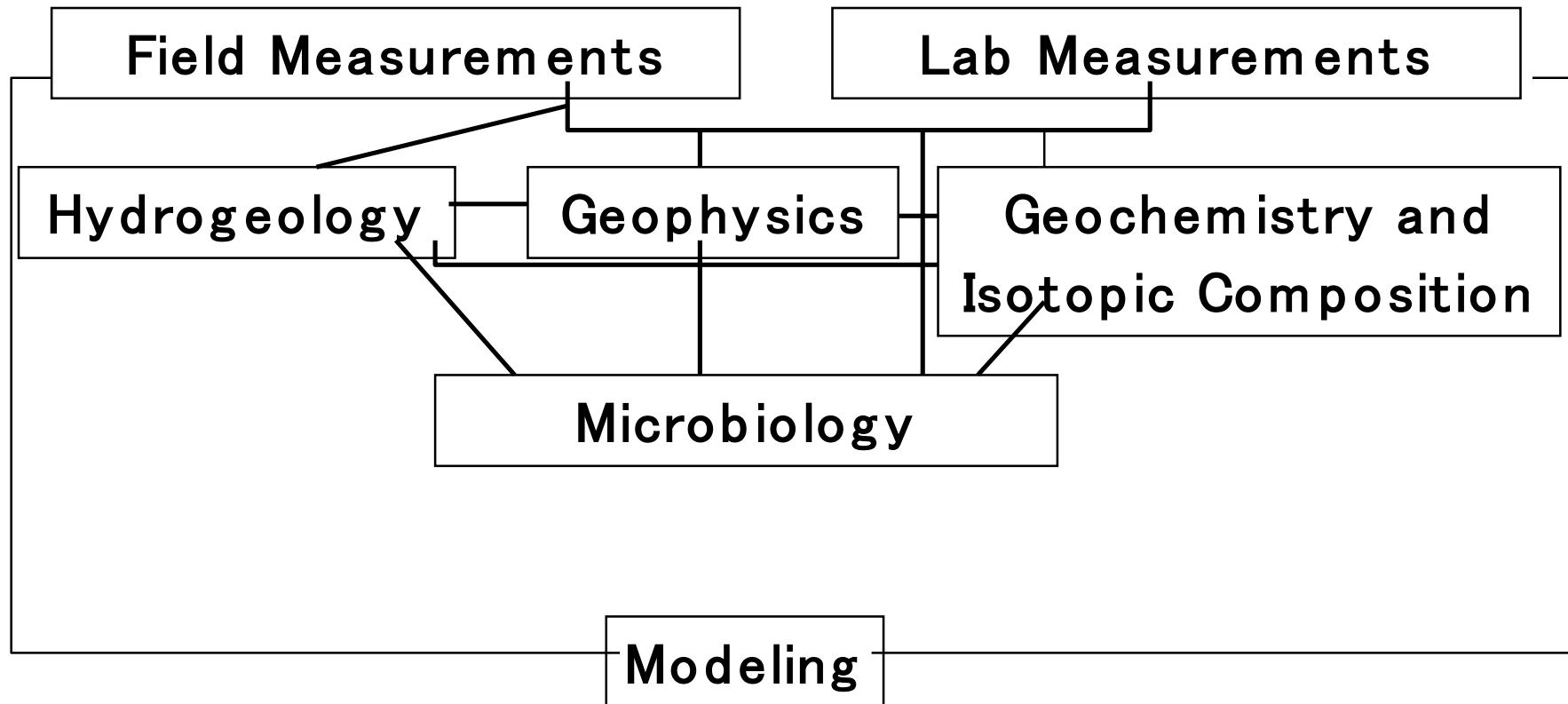
# **Year 2 – Field Testing and Monitoring to Assess a Possibility of Reoxidation and Enhancing the Effectiveness of Chromium Bioreduction**

**Task 5. Continuing field testing of Lactate (HRC) injection to stimulate chromium bioreduction in groundwater**

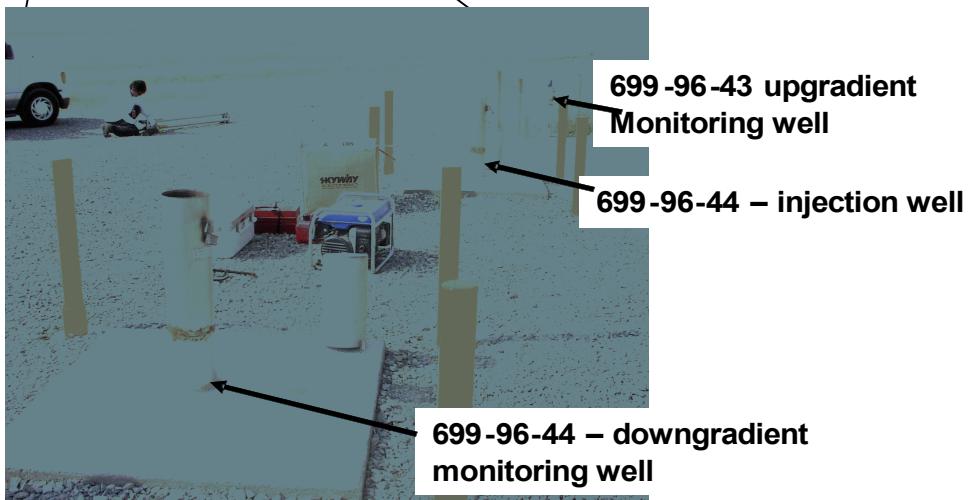
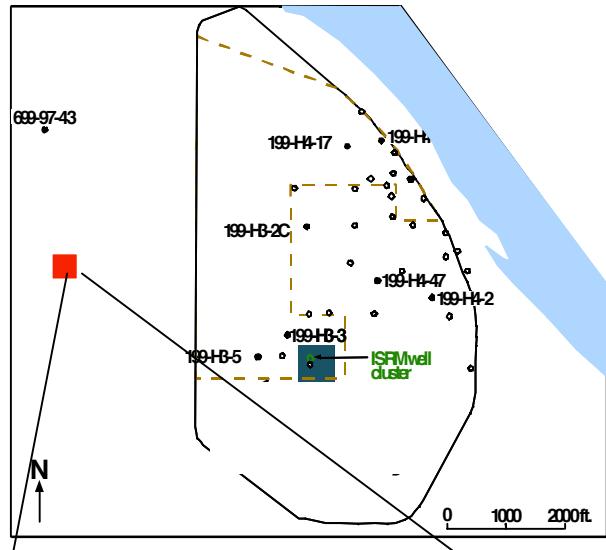
**Task 6. Post-test monitoring to assess biochemical processes caused by chromium bioreduction and possibility of chromium reoxidation**

**Task 7. Finalize the conceptual model of chromium bioreduction in groundwater on a field scale and recommendations for field deployment**

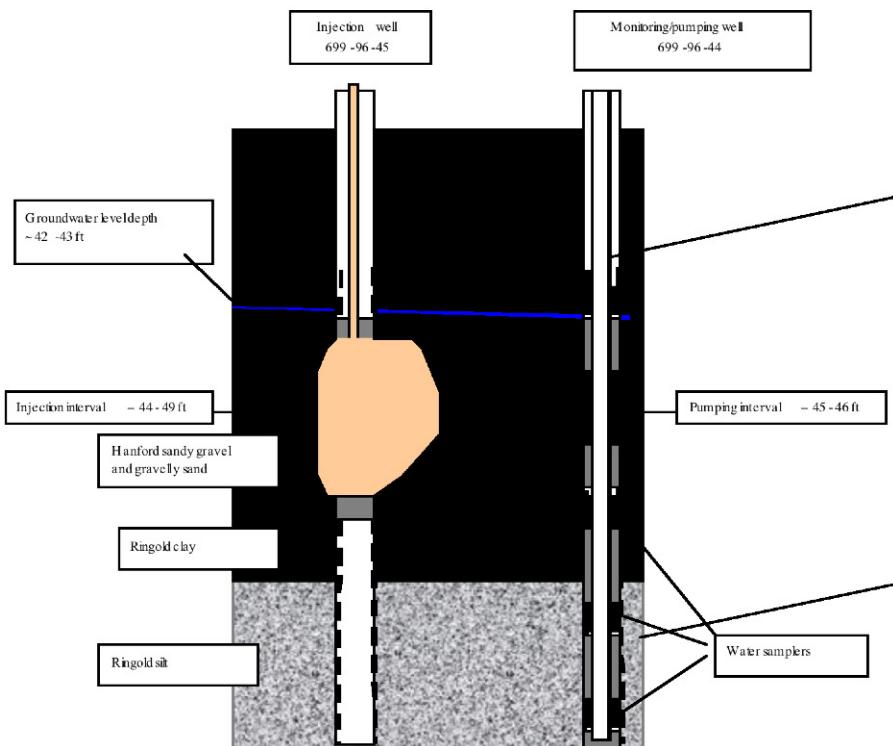
# Integrated Approach



# Hanford 100H Field site



## Well Design



Photographs of cores  
(4 in. diameter)



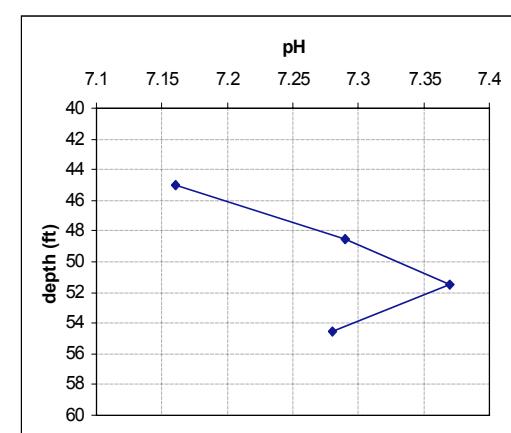
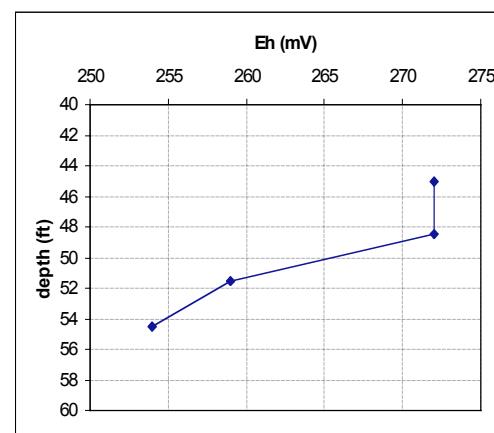
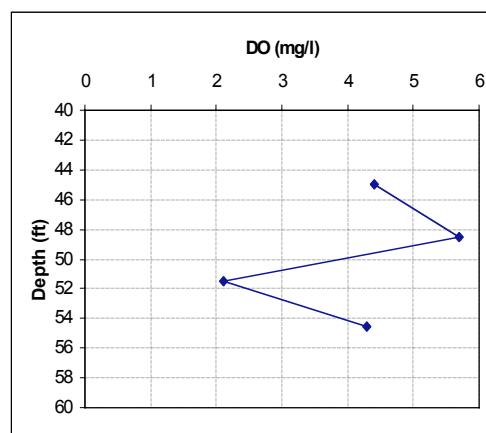
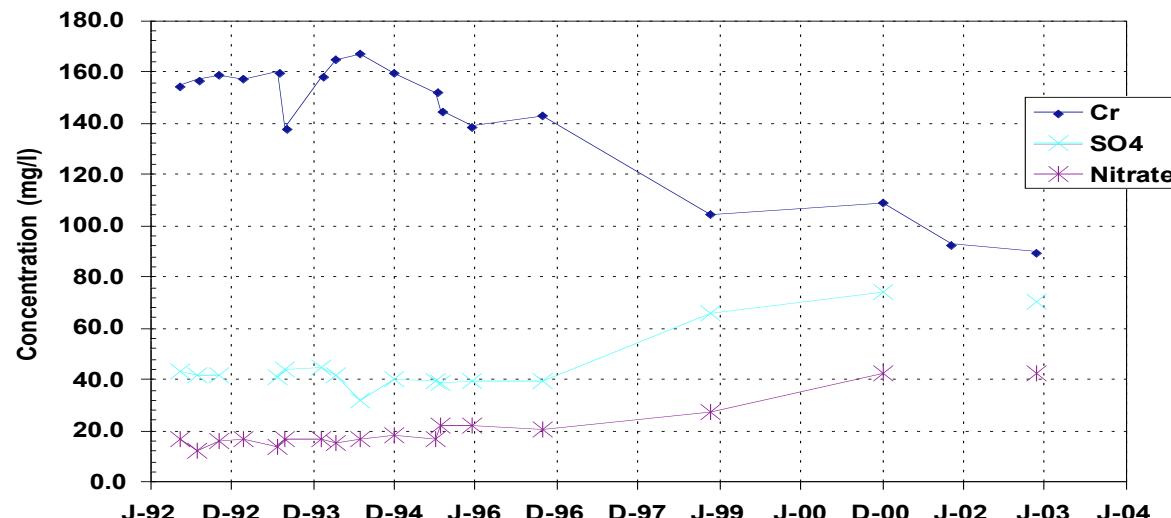
38.5 ft - Hanford  
gravelly sand



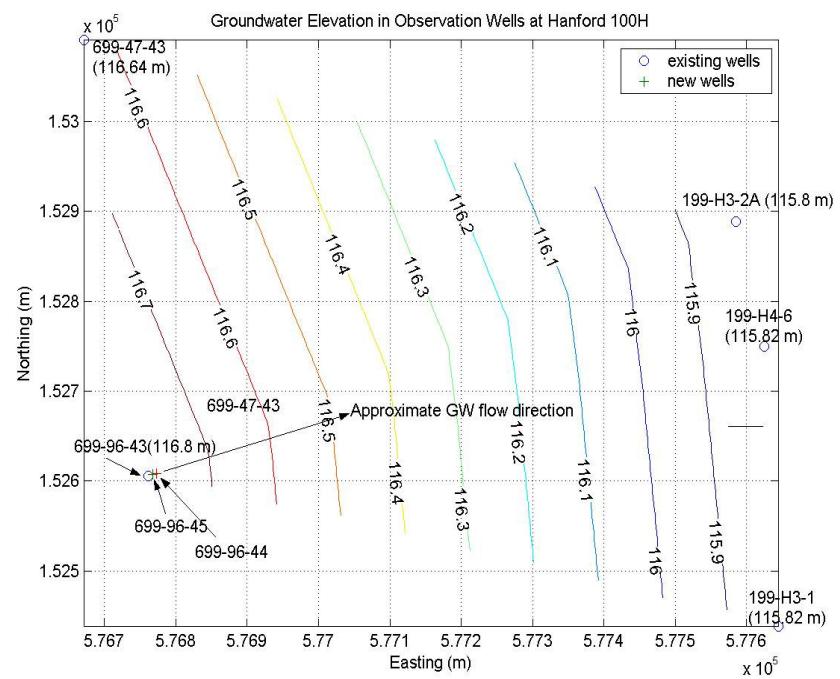
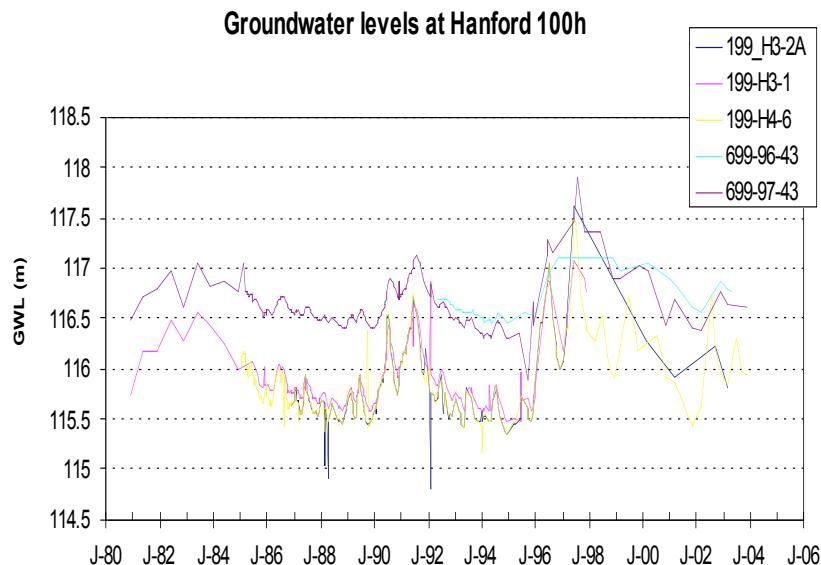
54 ft  
Ringold silt

# Background Concentrations and Groundwater Levels

Well 699-96-43

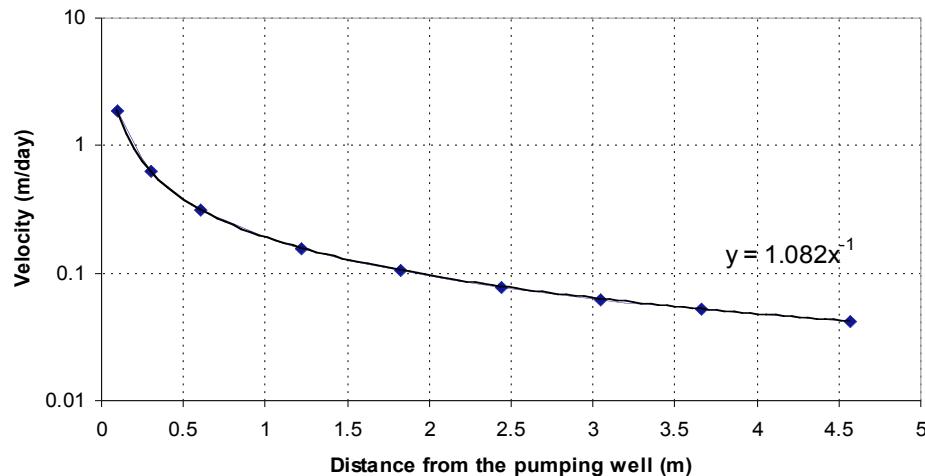


# Background Groundwater Levels

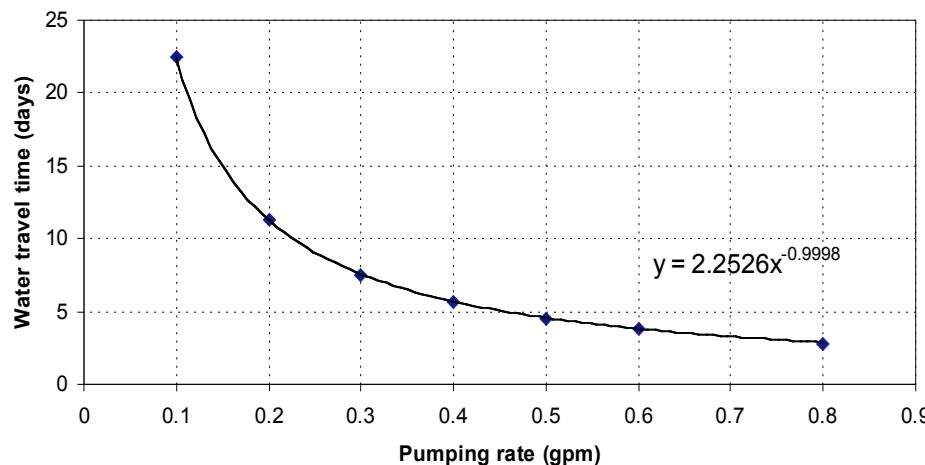


Groundwater elevation map (March 2004), showing locations of existing and new wells, which were located along the approximate direction of the regional groundwater flow.

# Br-Injection and Pumping Tests



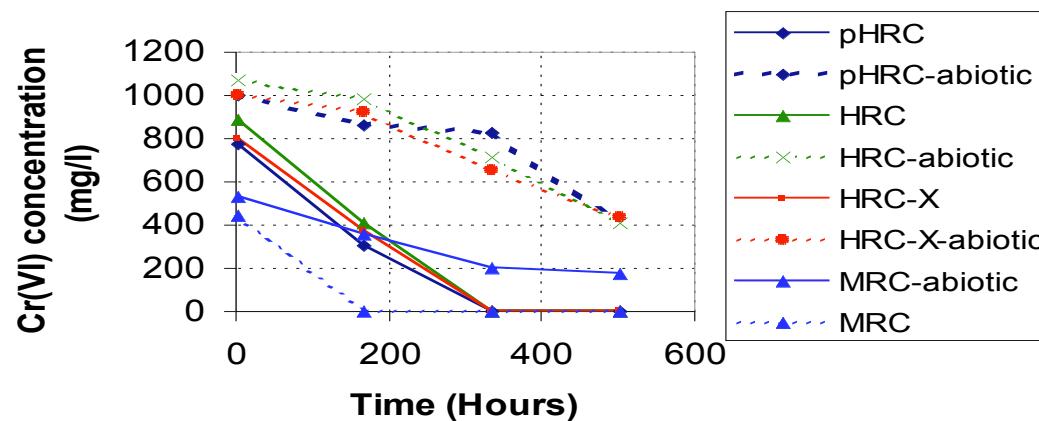
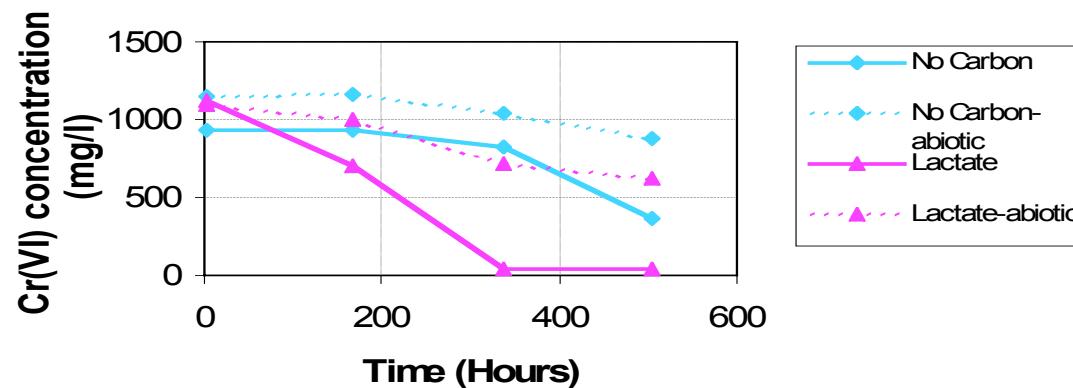
Water travel time between the injection and pumping wells vs.  
the pumping rate



$$K_s = 3.7 - 7.4 \text{ m/day}$$

Effective porosity = 0.26

# Microcosm Bench-Scale Study of Hanford Sediments



Decrease in Cr(VI), CO<sub>2</sub> and H<sub>2</sub> Concentration with Time as Affected by Different Treatment

# HRC Injection in Groundwater

- 40 lbs of <sup>13</sup>C-labeled HRC were injected, followed by Br-tracer injection, over the depth interval of 44 ft to 50 ft in the Hanford formation in Well 699-44-45 on 8/3/2004.
- All in all 11 gal of water were used as a primer to fill the injection hose before the injection, dilute HRC, and as a chaser after the HRC injection.
- Pumping from the monitoring well 699-96-44 (15 ft from the injection well) started immediately after the injection and continued for 27 days (until August 30).
- Br breakthrough occurred 7 days after the injection, and the maximum was reached 11 days after the injection.
- Microbial cell counts reached the maximum 13-17 days after the injection.



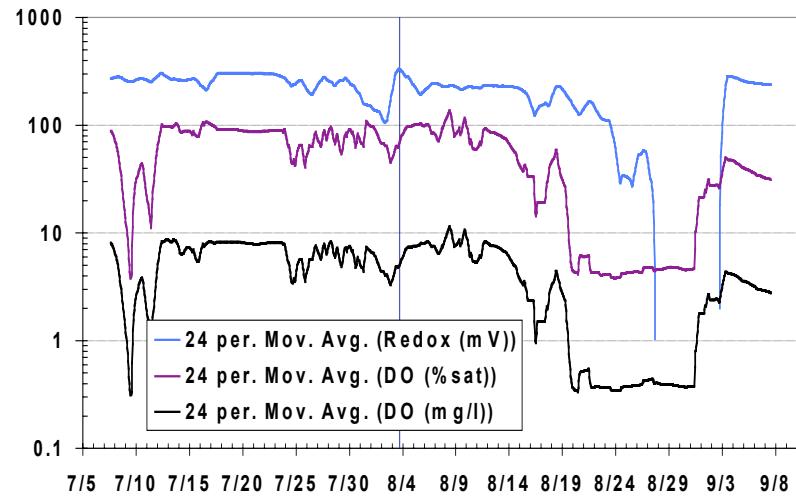
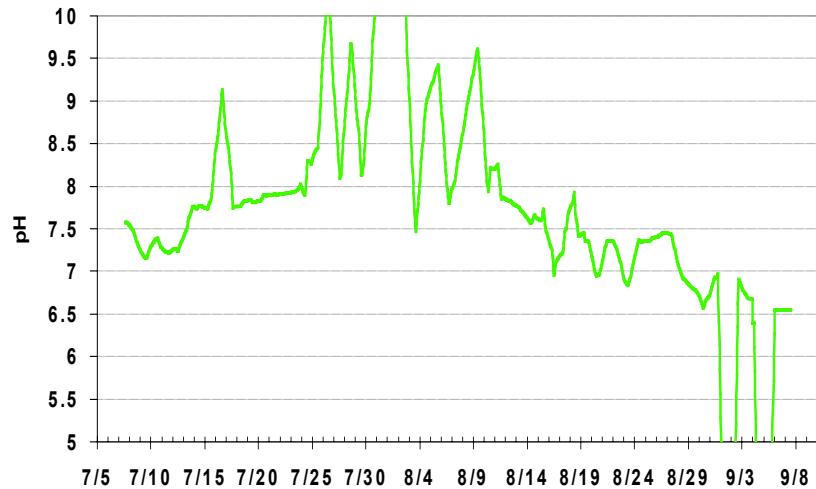
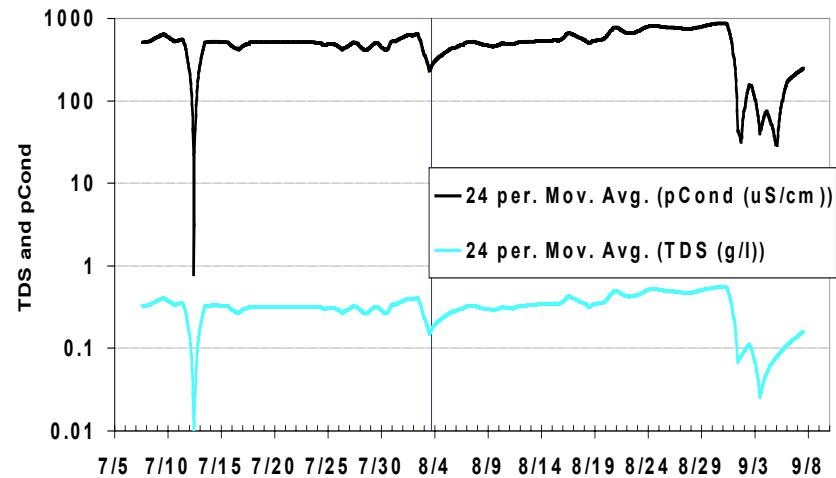
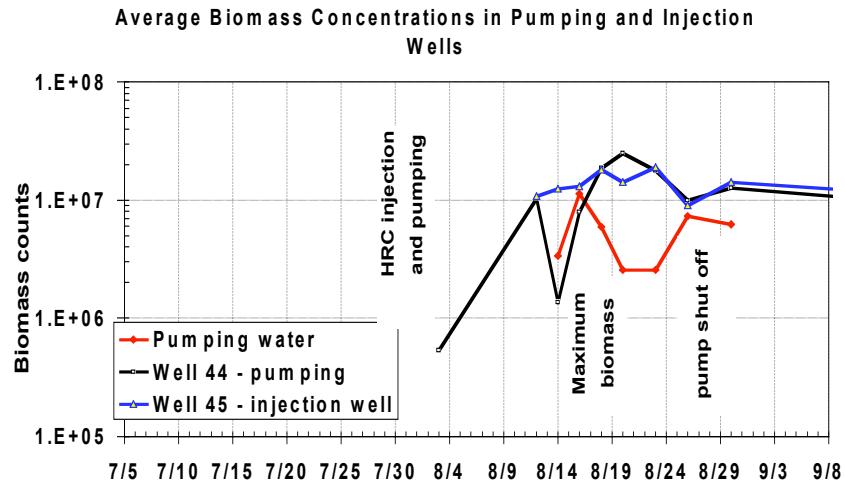
# Geophysical Measurements

- Pre-test surface GPR imaging:
  - Assessing spatial variabilit
  - Delineating hydrostratigraphy
- Pre-test and post-test seismic and radar tomographic velocity measurements between the injection and monitoring wells to delineate the HRC distribution

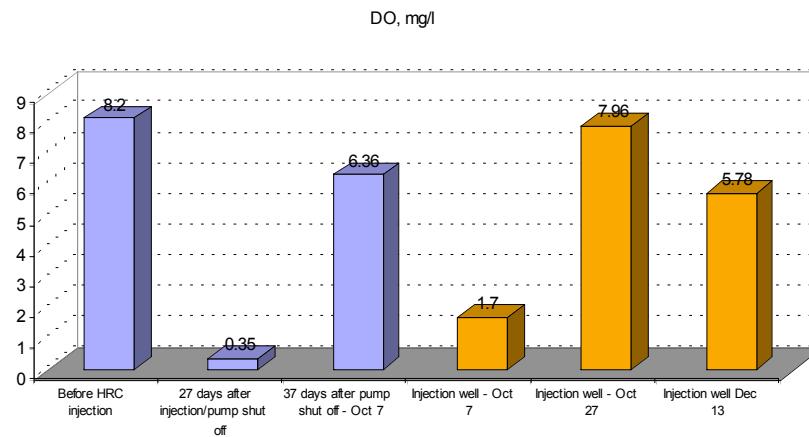
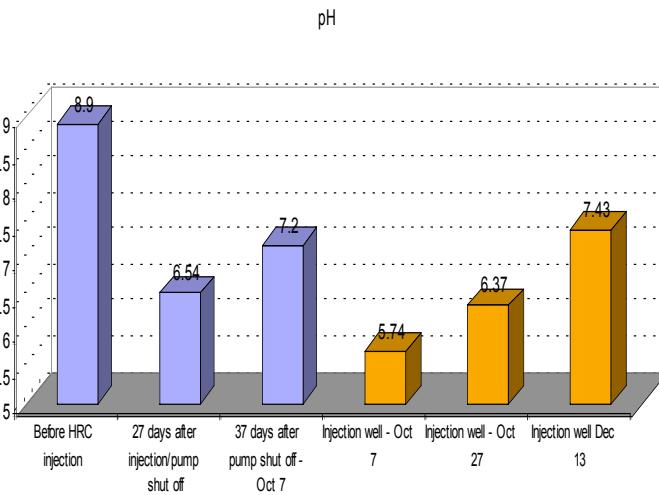
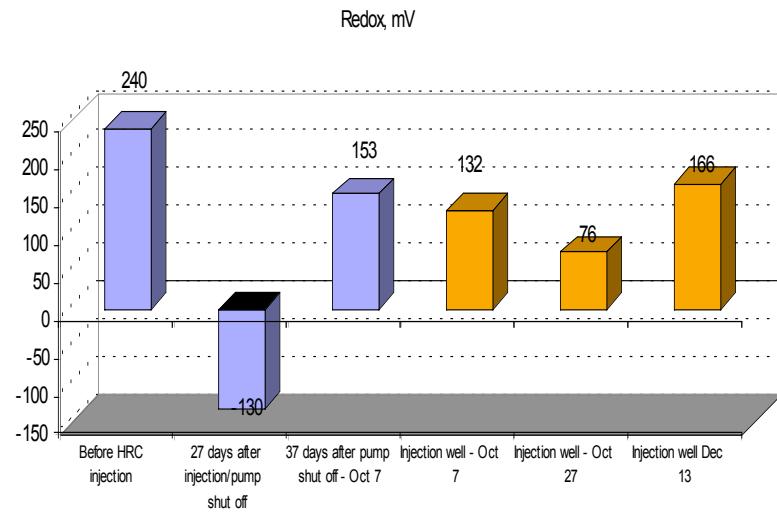
# Microbial Analyses

- Phospholipid fatty acid analyses (PLFA)
- Terminal restriction fragment length polymorphism (T-RFLP) with primers for Fe and sulfate reducers, and nitrate dissimilatory reactions
- Live/dead direct counts
- TEA, ED, DOC, DIC, CO<sub>2</sub>, O<sub>2</sub> Limiting nutrients, e.g., N, P, S, Fe
- Nitrogen and oxygen isotope ratio; <sup>53</sup>Cr/<sup>52</sup>Cr ratios
- Clone libraries
- 16S rDNA microarray analysis

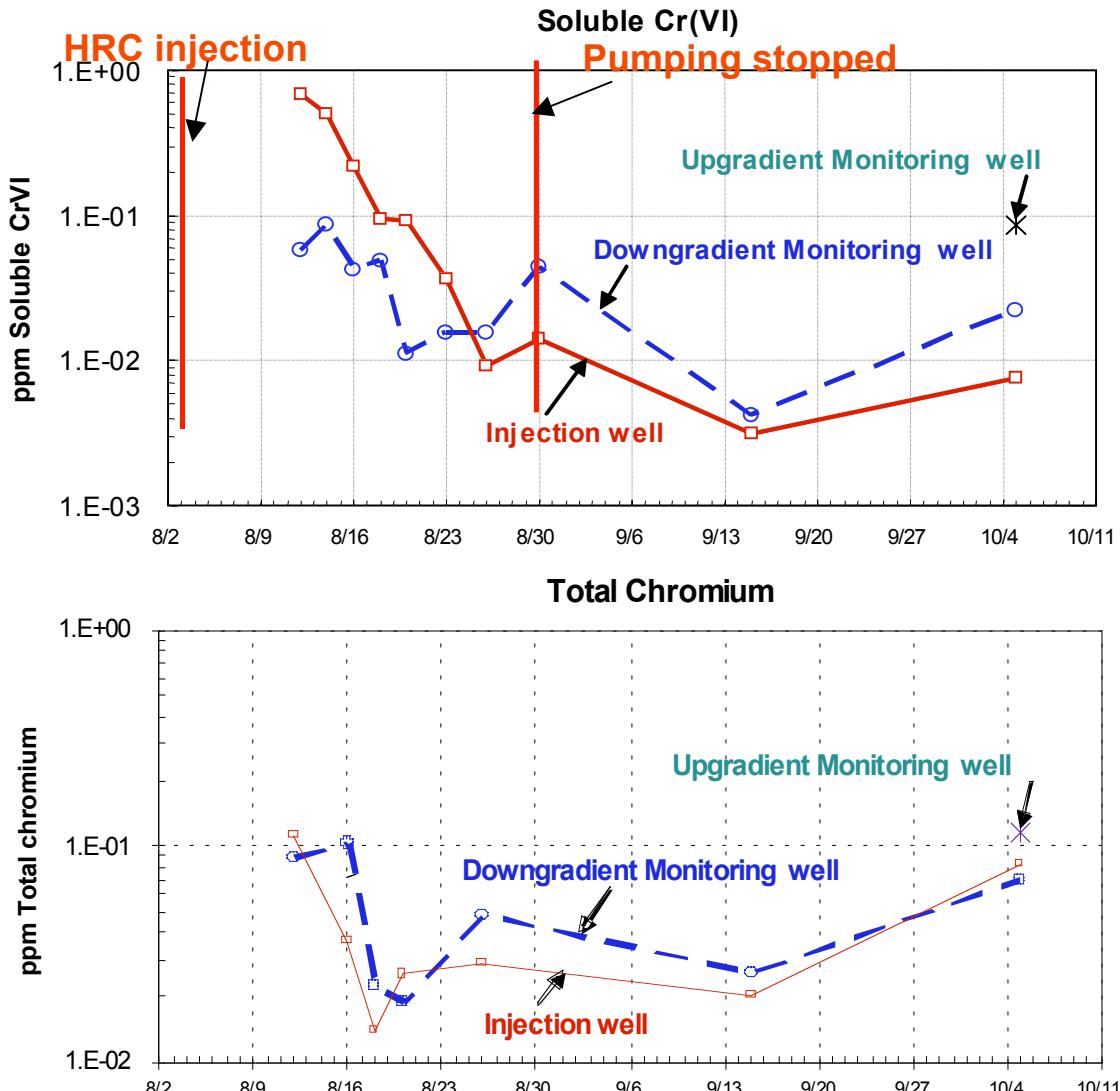
# Results of HRC Biosimulation



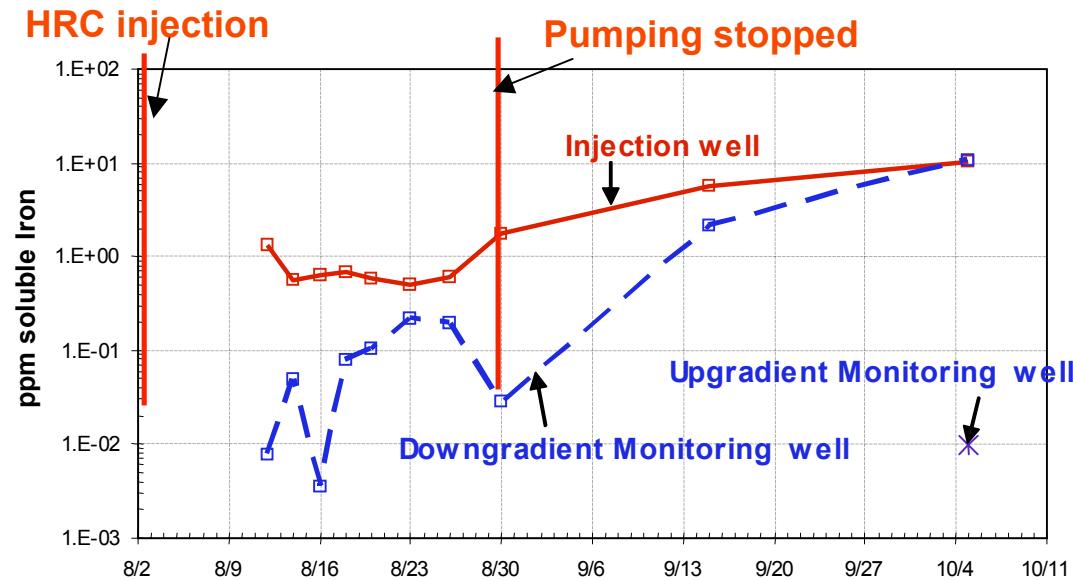
# Results of HRC Biosimulation



# Changes in Cr(VI) and Total Cr Concentrations after the HRC Injection



# Changes in Soluble Fe Concentrations after the HRC Injection



# Conclusions

- Under background conditions, Hanford sediments contain:
  - Low concentration of microbial populations ( $<10^5$  cells g-1)
  - Several types of bacteria, including *Bacillus/Arthrobacter* and *Geobacter* species, which are known to withstand high concentrations of heavy metals and reduce or sorb hexavalent chromium
- Pilot field-scale HRC injection in the groundwater generated:
  - An increase in the biomass up to  $2 \times 10^7$  cells g-1
  - Highly reducing conditions with DO of 0.35 mg/l, Redox Potential of -130 mV, and pH of 6.5
- Geophysical measurements are capable of monitoring the distribution of the HRC plume in the subsurface

# Summary of Accomplishments

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# Manuscripts to Publish

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